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Architecture Study for a Fuel Depot Supplied From Lunar Resources

Heretofore, discussions of space fuel depots assumed the depots would be supplied from Earth. However, the confirmation of deposits of water ice at the lunar poles in 2009 suggests the possibility of supplying a space depot with liquid hydrogen/liquid oxygen produced from lunar ice.

This architecture study sought to determine the optimum architecture for a fuel depot supplied from lunar resources. Four factors – the location of propellant processing (on the Moon or on the depot), the location of the depot (on the Moon, or at L1, GEO, or LEO), the location of propellant transfer (L1, GEO, or LEO), and the method of propellant transfer (bulk fuel or canister exchange) were combined to identify 18 potential architectures. Two design reference missions (DRMs) – a satellite servicing mission and a cargo mission to Mars – were used to create demand for propellants, while a third DRM – a propellant delivery mission – was used to examine supply issues. The architectures were depicted graphically in a network diagram with individual segments representing the movement of propellant from the Moon to the depot, and from the depot to the customer.

Delta-v and time-of-flight information were developed for each network segment using restricted two-body techniques. Propellant expended was calculated using the rocket equation, while anticipated boiloff was calculated using the modified Lockheed model. Chilldown losses were also calculated with respect to bulk fuel transfer. The depot was assumed to have active cooling of cryogens, while the DRM vehicles were assumed to employ passive insulation only. Overall, propellant consumption and losses were calculated in moving propellant to the depot, or in direct delivery to the customer. Similar consumption and losses were calculated for the customer DRMs in performing their missions and maneuvering to the depot or transfer location to refuel. The network diagram was then analyzed to determine which architecture satisfied the DRMs for the smallest mass of propellant.

The study concluded that an architecture in which water is shipped in bulk to a depot at L1 to be processed into propellant consumed/lost the least mass of propellants. L1 is the most efficient fuel transfer location because of delta-v considerations, and shipping water to the depot avoids boiloff losses en route, and avoids chilldown losses between the tanker vehicles and the depot. For all candidate architectures, propellant boiloff in microgravity was less a factor than anticipated, and was far overshadowed by delta-v requirements and resulting fuel consumption. Bulk fuel transfer is the most flexible for both the supplier and the customer. However, since canister exchange bypasses the transfer of bulk cryogens in microgravity and the necessary chilldown losses, canister exchange shows promise and merits further investigation. Overall, this work indicates propellant consumption and loss is an essential factor in assessing fuel depot architectures.